REDUCTION OF WATER HARDNESS USING PLANT PARTS

T. D. K. S. Kumara[1], M. D. J. S. Saparamadu[2] and M. Thayaparan[3]

[1, 2, 3] *Department of Chemistry, The Open University of Sri Lanka*

INTRODUCTION

In Sri Lanka, the quality of potable water is governed by Sri Lanka Standards Institute standard SLS 614: 1983, which describes the physical, chemical and biological qualities of potable water safe for human consumption. Water hardness can be defined as the sum of polyvalent cations present in water (Benefield and Morgan, 1990) and also defined as the total concentration of alkaline earth (Group 2) ions, which are mainly Ca^{2+} and Mg^{2+}. Hardness is usually expressed as the equivalent amount of $CaCO_3$ in mg *per* litre. Assuming that concentrations of other polyvalent cations are negligible, hardness can be classified as magnesium hardness or calcium hardness; total hardness being the sum of the two. Based on the associated anions, hardness can be classified as temporary (caused by HCO_3^-) or permanent (caused by Cl^- and SO_4^{2-}). Effects of hardness can be mostly on industries and health. Effects on industries are mainly due to formation of scale inside water pipes. Health effects of hardness are disputed. The World Health Organization (2011) states that hardness levels found in drinking water are not of any health concern. An important issue in hard water is the objectionable taste introduced by ions present. There are many methods to reduce hardness. Chemical methods involve lime softening, ion-exchange softening and chelation. Electrocoagulation (Malakootian and Yousefi, 2009) is an example of a physical hardness removal method. All these methods are either expensive or difficult to implement because of the technical knowledge and skills required. If plant parts can remove or reduce water hardness, it would be an economical, environmentally sustainable and user-friendly alternative method compared to other methods of hardness removal. It would be useful to compare this method with boiling and analyze the combined effect of boiling and plant adsorption on water hardness.

The objectives of this research were to determine the levels of water hardness in some selected areas in Sri Lanka before and after boiling, to determine suitable plant parts to reduce hardness and to optimize reduction of hardness by the selected plant parts with respect to weight and time of equilibration on un-boiled hard water.

METHODOLOGY

In order to determine the hardness levels in Sri Lanka, nine locations (wells (W) and tube wells (T)) in North and North-Central provinces were selected (Anuradhapura (A)-3, Jaffna (J)-4, Madawachchiya (M)-1 and Vavuniya (V)-1). Three samples of surface water were taken from each location and were analyzed before and after boiling using the following methods; calcium hardness: filtered samples were analyzed using flame photometry, total hardness: added 2.0 ml of pH 10 buffer to 25.0 ml of filtered samples and titrated against 0.01 M EDTA with EBT indicator, magnesium hardness: the difference between total and calcium hardness. pH of each sample was also recorded. Based on the results, 2 levels of hardness were decided (L1: average hardness before boiling, L2 : average hardness after boiling). Synthetic hard water was prepared using $CaCO_3$ and $MgCO_3$ while maintaining similar pH levels (with the use of dilute HCl and NH_4OH).

The following plant parts were chosen for this study: Moringa (<u>*Moringa oleifera Lam.*</u>) bark – air dried (3 cm x 1.5 cm), rice hull – air dried - uncrushed and crushed (600 μm < size < 1.18

[2] All correspondences should be addressed to Mrs. M. D. J. S. Saparamadu, Department of Chemistry, The Open University of Sri Lanka, Nawala, Nugegoda (Email: mdsap@ou.ac.lk)

mm), Nelli (*Phyllanthus emblica*) flesh - raw and water melon (*Citrullus lanatus*) seeds – air dried. Known weight of each plant part was equilibrated with 100 ml of hard water in a mechanical shaker for 1 hour. Three replicates were analyzed for each level of hardness for each plant part. After equilibration, the samples were filtered and analysed for total and calcium hardness. Based on the results, Moringa bark and crushed rice hull were chosen for optimization. Optimization with respect to weight was done by equilibrating different weights of plant parts (1 – 10 g) with 100 ml of hard water (L1) for 3 hours. Then the samples were filtered and analyzed. Based on the results, best weights were chosen from the selected plant parts and optimization was carried out with respect to time by equilibrating known weights of plant materials with 100 ml of hard water (L1) for different time periods (3 – 24 hours).

RESULTS AND DISCUSSION

A large variation of hardness was detected among the tested water samples from North and North-Central provinces (AW1 = 757 ppm, AW2 = 330 ppm, AW3 = 360 ppm, JT1 = 760 ppm, JT2 = 760 ppm, JW1 = 881 ppm, JW2 = 490 ppm, MW = 770 ppm, VW = 820 ppm).

Table 1 - Levels of hardness and composition of synthetic hard water (Hardness in ppm)

Level	Description	Total hardness	Calcium hardness	Magnesium hardness
L1	Un-boiled	850	475	375
L2	Boiled	600	240	360
	% reduction by boiling	29 %	49 %	4 %

In order to represent the total range of hardness, AW1, JW1 and VW samples were chosen for this study. According to the results, total hardness can be reduced by 29 % and calcium hardness by 49 % by boiling. Magnesium hardness is not considerably affected by boiling. This shows that in Sri Lanka, it is calcium hardness that contributes more to total hardness. It might be possible that the major amount of magnesium hardness is present in the form of sulphates and chlorides causing permanent hardness. Based on these results, two levels of total hardness were decided upon; L1: before boiling, L2: after boiling.

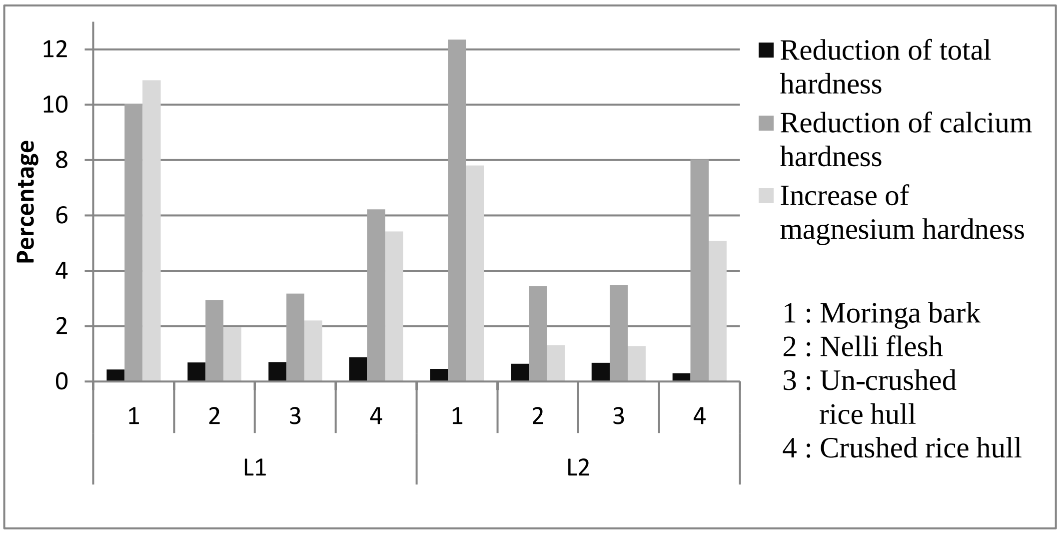
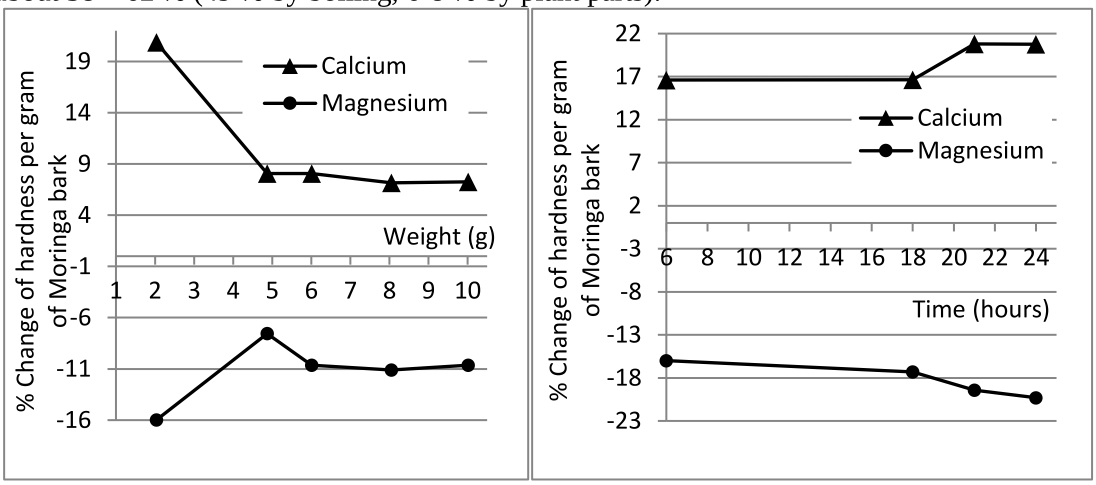


Figure 1 - Efficacy of plant parts in removing hardness at levels L1 and L2.

Figure 1 depicts the results for efficacy of plant parts in reducing hardness at L1 and L2. Plant parts for this study were selected depending on their availability in areas where there are higher levels of hardness and cost. The ability of reducing calcium hardness was in the following order; Moringa bark (10 – 12 %), crushed rice hull (6 – 8 %), Un-crushed rice hull ≈ Nelli flesh (3 %).

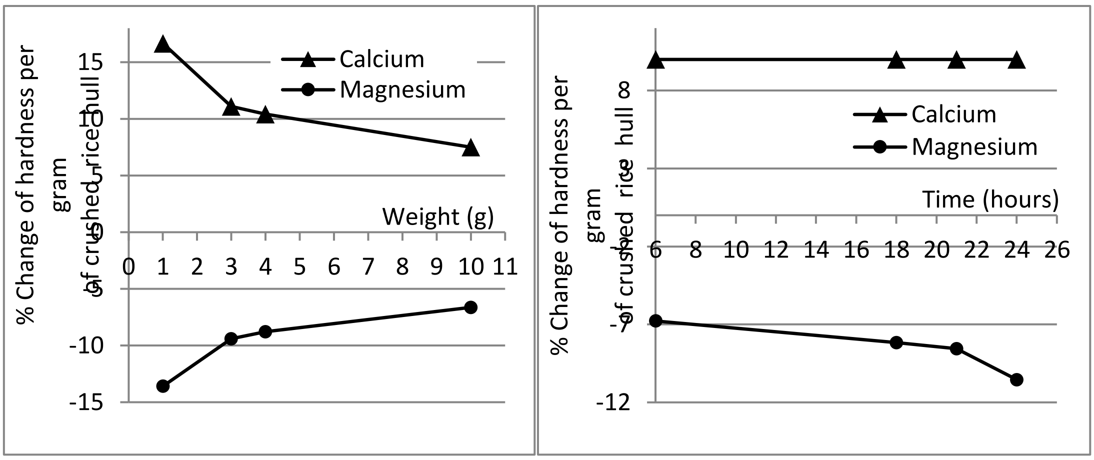
An interesting observation is that, while calcium hardness is reduced, magnesium hardness is increased, thus resulting in no effect on total hardness. This might be due to leaching of magnesium from the plant material. Crushed rice hull showed a higher ability to reduce calcium hardness at both levels than un-crushed rice hull. Water melon seeds were not taken for the study because of excessive leaching of organic substances under equilibration which gave an extensive coloration to the solution, interfering in the analysis. Based on the results Moringa bark and crushed rice hull were selected as suitable plant parts for optimization.

The results show that both Moringa bark and crushed rice hull show a higher ability (about 2 % more) in reducing calcium hardness in boiled water compared to un-boiled water thus showing a higher efficacy when applied to boiled water. It can be concluded that when boiling is combined with application of these plant parts, the calcium hardness can be reduced by about 58 – 62 % (49 % by boiling, 6-8 % by plant parts).



2(a) 2(b)

Figure 2(a) - Results for weight optimization with Moringa bark.
2(b) - Results for time optimization with Moringa bark.



3(a) 3(b)

Figure 3(a) - Results for weight optimization with crushed rice hull.
3(b) - Results for time optimization with crushed rice hull.

Figure 2(a) depicts the result for weight optimization for Moringa bark (negative values of magnesium hardness denote increase of magnesium hardness by leaching). According to the results in Figure 2(a), the best weight of Moringa bark in reducing calcium hardness is 2 g. It is also noticeable that, as the weight increases, the efficacy of removing calcium hardness initially decreases and remains constant for more than 5 g. At any given weight, removal of calcium hardness is approximately similar to increase of magnesium hardness. According to Figure 2(b), best time period for reducing calcium hardness by Moringa bark is 6 - 16 hours. A similar pattern can be observed for crushed rice hull as well (Figure 3(a) and 3(b)). The best weight for reducing calcium hardness using crushed rice hull is 2g. According to figure 3(b), time of equilibration does not have an effect on removing calcium hardness with crushed rice hull.

CONCLUSIONS / RECOMMENDATIONS

Boiling of the hard water reduces the total hardness by 29 % and calcium hardness by 49 %. Magnesium hardness is not considerably affected by boiling. Although Moringa bark and crushed rice hull cannot be applied for removal of total hardness, it can be used to reduce calcium hardness. Moringa bark has the highest ability to reduce hardness in both boiled and un-boiled water. (Calcium hardness in un-boiled water by 10 % and in boiled water by 12 %) Crushed rice hull has the ability to reduce calcium hardness by 6 % in un-boiled water and in boiled water the efficiency is 8 %. According to the results of optimization, best weight of Moringa bark is 2 g with time period of 6 – 16 hours. For crushed rice hull, best weight is 1g with time period of 6 hours.

It is recommended that this study be carried out using lower weights of plant parts in order to explore the possibility of obtaining a greater hardness reducing efficiency. It is also possible to determine hardness reducing efficacies of different plant parts using the above procedure. Since synthetic hard water used in this study consists of mostly permanent hardness, it can be recommended that the same plant parts be used against naturally occurring hard water to determine whether there is a difference in effectiveness.

REFERENCES

Benefield L. D., Morgan J. M. (1990). Chemical Precipitation. *In*: Letterman R. D. (Ed). Water quality and treatment: A handbook of community water supplies. 4th Ed. New York, Mc-Graw Hill Inc, US.

World Health Organization (2011). Guidelines for Drinking-water Quality. 4th Ed. Geneva, World Health Organization.

Malakootian M, Yousefi N. (2009). The efficiency of electrocoagulation process using Aluminum electrodes in removal of hardness from water. Iran. J. Environ. Health. Sci. Eng. 6(2): 131-136.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Prof. K.S.D. Perera, Mr. D. R. Kulatunga, Mrs. Nisansala Bopage, staff and the technical staff of the Department of Chemistry.